

# UV and FIR selected star-forming galaxies at $z=0$ : differences and overlaps

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## ABSTRACT

We study two samples of local galaxies, one is UV (GALEX) selected and the other FIR (IRAS) selected, to address the question whether UV and FIR surveys see the two sides ('bright' and 'dark') of the star formation of the same population of galaxies or two different populations of star forming galaxies. No significant

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difference between the  $L_{tot}$  ( $= L_{60} + L_{FUV}$ ) luminosity functions of the UV and FIR samples is found. Also, after the correction for the ‘Malmquist bias’ (bias for flux limited samples), the FIR-to-UV ratio v.s.  $L_{tot}$  relations of the two samples are consistent with each other. In the range of  $9 \lesssim \log(L_{tot}/L_{\odot}) \lesssim 12$ , both can be approximated by a simple linear relation of  $\log(L_{60}/L_{FUV}) = \log(L_{tot}/L_{\odot}) - 9.66$ . These are consistent with the hypothesis that the two samples represent the same population of star forming galaxies, and their well documented differences in  $L_{tot}$  and in FIR-to-UV ratio are due only to the selection effect. A comparison between the UV luminosity functions shows marginal evidence for a population of faint UV galaxies missing in the FIR selected sample. The contribution from these ‘FIR-quiet’ galaxies to the overall UV population is insignificant, given that the K-band luminosity functions (i.e. the stellar mass functions) of the two samples do not show any significant difference.

*Subject headings:* dust: extinction – galaxies: luminosity function, mass function  
– infrared: galaxies – ultraviolet: galaxies

## 1. Introduction

The evolution of star forming galaxies tells much about the history of the universe. The star formation activity in these galaxies can be best studied by observing the emission from young massive stars in the rest frame UV and FIR. The UV observations record the direct light from the hot young stars, and the FIR observations collect star light absorbed and then re-emitted by the ubiquitous dust. A complete picture of star formation in the universe can only be obtained when the observations in these two wavebands are properly synthesized. Indeed, our knowledge on the star formation history of the universe has been mostly derived from deep surveys in the rest frame UV and FIR. Many studies have been devoted to methods of deriving star formation rate of individual galaxies using the UV or FIR luminosities (Calzetti 1997; Meurer et al. 1999; Buat & Xu 1996; Iglesias-Páramo et al. 2005), and the strengths and shortcoming of these methods have been discussed thoroughly in the literature (Kennicutt 1998; Adelberger & Steidel 2000; Bell 2002; Bell 2003; Buat et al. 2005; Kong et al. 2004; Iglesias-Páramo et al. 2006). However, an arguably more important issue is the selection effect of the surveys that can be summed up by the following question: Do UV and FIR surveys see the two sides (‘bright’ and ‘dark’) of the star formation of the same population of galaxies, or do they see two different populations of star forming galaxies? This is important because if the correct answer is the latter, then even if one can estimate accurately the star formation rate for galaxies in surveys in one band, the star

formation in galaxies detected in the other band is still missing. Actually this question is in the core of an on-going debate on whether the SFR of  $z \sim 3$  universe can be derived from observations of Lyman-break galaxies, which are UV selected star forming galaxies at  $z \sim 3$  (Adelberger and Steidel 2000), given that SCUBA surveys in sub-millimeter (rest frame FIR for  $z \gtrsim 2$ ) detected many violent star forming galaxies at about the same redshift that are not seen by LBG surveys (Smail et al. 2001; Smail et al. 2004).

There have been limited overlaps between rest frame UV surveys and rest frame IR surveys. In the SCUBA survey of LBG's (Chapman et al. 2000), only one LBG was detected. As summarized in Adelberger and Steidel (2000), only a couple of SCUBA sources are bright enough in optical to be detected in LBG surveys. The situation is better for  $z \sim 1$  star forming galaxies, which now can be routinely identified by large scale spectroscopic surveys and multi-band optical surveys, and which have been detected in abundance in mid-infrared by ISOCAM deep surveys (Elbaz et al. 2002; Hammer et al. 2005) and Spitzer surveys (Le Floch 2005), and in UV by GALEX (Arnouts et al. 2005; Burgarella et al. 2006). However the extrapolation from the mid-IR to the total dust emission is very uncertain and may subject to significant evolution itself. The same criticism can also be applied to the comparisons between rest frame UV and MIR sources at  $z \sim 2$ , the latter being detected recently by Spitzer at  $24\mu m$  (Chary et al. 2004; Shupe et al. 2005). Because of the relatively high confusion limits for surveys in the Spitzer MIPS  $70\mu m$  and  $160\mu m$  bands, thorough comparisons of rest frame UV and FIR sources of  $z \gtrsim 1$ , down to luminosity levels fainter than the 'knee' of the luminosity functions of both bands, may have to wait until the launch of Herschel (Pilbratt 2005).

In this paper, we investigate the difference and overlaps of the UV and FIR selected samples in the local universe in an attempt to shed light on the selection effects of high- $z$  samples similarly selected. The UV data are taken from observations by Galaxy Evolution Explorer (GALEX) and the FIR data are taken from the IRAS database. Several papers have been published using these data. Martin et al. (2005, hereafter M05) derived the local ( $z=0$ ) bivariate luminosity function for the FUV ( $1530\text{\AA}$ ) and FIR ( $60\mu m$ ) bands, which shows that the FUV luminosity saturates at about  $2 \cdot 10^{10} L_{\odot}$  while the FIR luminosity can be as high as  $\sim 10^{13} L_{\odot}$ . This is consistent with a very strong dependence of the FIR/FUV ratio on the total luminosity ( $L_{\text{tot}} = L_{\text{FIR}} + L_{\text{FUV}}$ ). The luminosity function of  $L_{\text{tot}}$  has a log-normal form. Buat et al. (2005) compared the extinction properties of local UV and FIR selected galaxies and found that the mean NUV ( $2267\text{\AA}$ ) extinction of UV selected galaxies is significantly lower than that of FIR selected galaxies ( $\sim 1$  mag vs.  $\sim 2.5$  mag). Iglesias-Páramo et al. (2006) carried out an extensive study, using combined GALEX and IRAS data, on the UV and FIR emission as star formation indicators and found a rather modest star formation activity for local star forming galaxies. Pre-GALEX studies on comparisons between UV

and FIR selected samples can be found in Buat & Burgarella (1998), Buat et al. (1999) and Iglesias-Páramo et al. (2004). In this work, we will study some statistics free of the selection effect in order to check quantitatively how much the UV and FIR selected samples differ/overlap with each other. The paper is arranged as following: After this introduction, the data sets analyzed in this paper are presented in Section 2. Major results are listed in Section 3. Section 4 is devoted to the discussion. Through out this paper, we assume  $\Omega_{\Lambda} = 0.7$ ,  $\Omega_m = 0.3$ , and  $H_0 = 70 \text{ km sec}^{-1} \text{ Mpc}^{-1}$ .

## 2. Data

The data sets are basically the same as those in Iglesias-Páramo et al. (2006) and Buat et al. (2005). The original UV selected sample (Iglesias-Páramo et al. 2006) includes 95 galaxies brighter than  $\text{NUV} = 16 \text{ mag}$  selected from GALEX G1 stage All-sky Imaging Survey (AIS), covering  $654 \text{ deg}^2$ . From these we exclude 1 galaxy, 2MASX\_J20341333-0405, which does not have measured redshift. The FIR selected sample is also taken from Iglesias-Páramo et al. (2006). From the original sample, including 163 galaxies with  $f_{60} \geq 0.6 \text{ Jy}$  in  $509 \text{ deg}^2$  sky covered both by GALEX AIS and IRAS PSCz (Saunders et al. 2000), 2 are excluded: NGC 7725 (no redshift) and IRAS-F00443+1038 (not a galaxy). Consequently, the UV and FIR selected samples studied in this paper have 94 and 161 galaxies, respectively. The  $K_s$  ( $2.16\mu\text{m}$ ) band magnitudes  $K_{\text{tot}}$  are taken from Extended Source Catalog (XSC) of 2MASS (Jarrett et al. 2000). Since this is very close to the classical K ( $2.2\mu\text{m}$ ) magnitude, we will call it K magnitude hereafter for the sake of simplicity. For both the UV selected sample (94 galaxies) and the FIR selected sample (161 galaxies), each has 12 galaxies undetected by 2MASS. According to the sensitivity limit of 2MASS XSC (Jarrett et al. 2000), upper limits of  $K=13.5 \text{ mag}$  are assigned to the undetections.

Morphological classifications were searched in NED. For those galaxies without morphological classification in the literature, images taken from SDSS, DSS and 2MASS (in the order of priority) were inspected and eye-ball classification was carried out. Galaxies included in Atlas of Peculiar Galaxies (Arp 1966), Southern Peculiar Galaxies and Associations (Arp & Madore 1987), and Catalog of Isolated Pairs of Galaxies (Karachentsev 1972) are classified as peculiar, interacting or mergers. For a few galaxies that are faint ( $b > 15 \text{ mag}$ ) and small ( $\lesssim 10''$ ) the classification can be very uncertain. Most of such galaxies are in the FIR selected sample, and very often there is clear sign of interaction (close companion of similar brightness and/or diffuse tidal features). In Fig.1 the distributions of morphological types (not including QSOs and ellipticals) of the two samples are compared. The overall overlap between the two distributions is about 60%. There is a significant excess

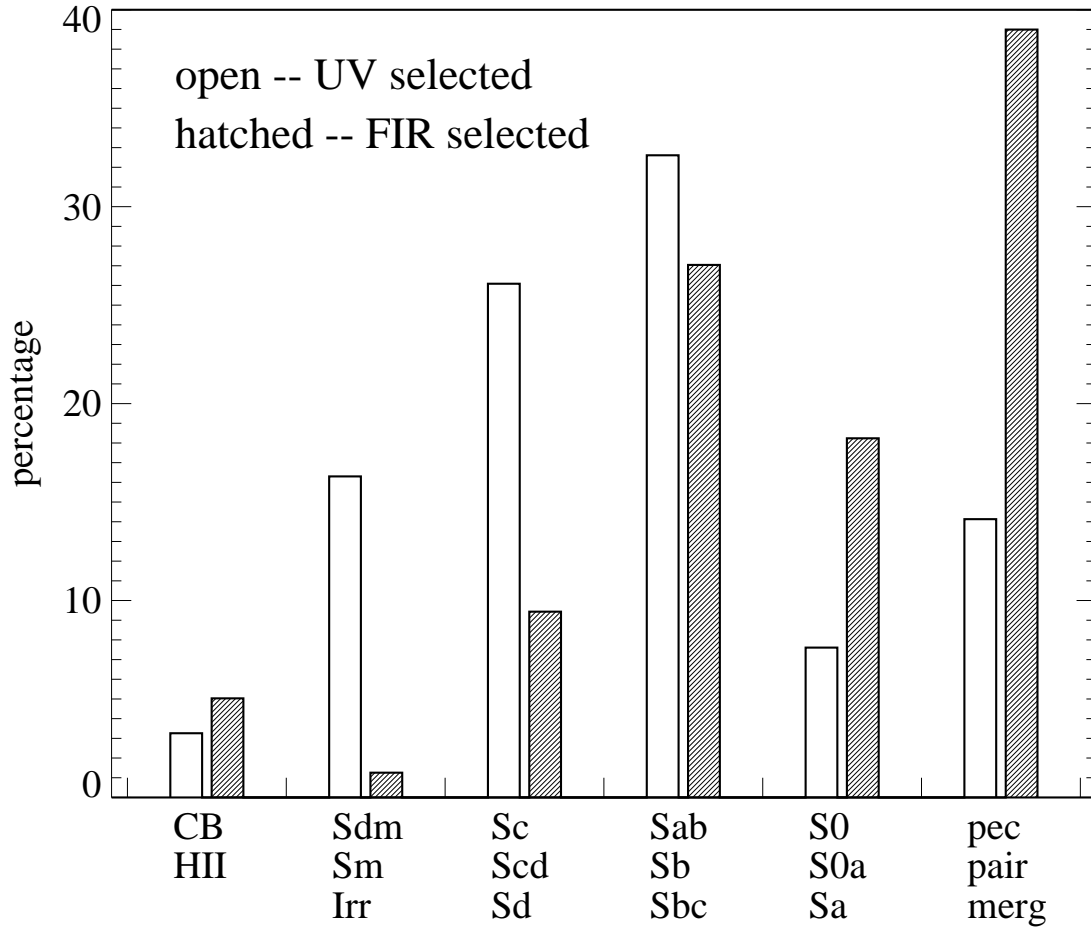


Fig. 1.— Morphological type distributions of the UV and FIR selected samples.

of Pec/Int/merg galaxies in the FIR selected sample (39%) compared to those in the UV selected sample (14%). For normal galaxies both UV and FIR selected samples peak in the bin of Sab/Sb/Sbc. Detailed analysis shows that the median type for normal UV galaxies is Sc and that of normal FIR galaxies is Sb. The FIR selected sample is tilted toward the earlier spirals whereas the UV sample has more late type (later than Sc) galaxies.

### 3. Results

#### 3.1. Comparisons of luminosity functions of UV and FIR galaxies

Much of the difference between UV and FIR selected samples can be traced back to a single selection effect: UV observations detect preferentially galaxies with low  $L_{FIR}/L_{UV}$  ratios, and in contrast FIR observations select galaxies with high  $L_{FIR}/L_{UV}$  ratios. Since the FIR/UV ratio is a good indicator of dust attenuation (Xu & Buat 1995; Buat & Xu 1996; Meurer et al. 1999; Gordon 2000), it follows that UV samples select galaxies with significantly lower dust attenuation than galaxies in the FIR selected sample: Buat et al. (2005) found a median FUV attenuation of  $A(FUV) = 0.8^{+0.3}_{-0.3}$  mag for the UV selected sample, compared to a  $A(FUV) = 2.1^{+1.1}_{-0.9}$  mag for the FIR selected sample.

It has been well established that there is a strong correlation between luminosity and dust attenuation in the sense that more luminous galaxies have higher dust attenuation (Wang & Heckman 1996; Buat & Burgarella 1998; Adelberger & Steidel 2000; M05). Fig.2 shows that galaxies in both FIR and UV samples follow the strong  $L_{60}/L_{UV}$  vs.  $L_{tot}$  correlation. On the other hand, UV galaxies in general have significantly lower  $L_{tot}$  and lower  $L_{60}/L_{UV}$  ratios for a given  $L_{tot}$  compared to FIR galaxies (Buat & Burgarella 1998; Adelberger & Steidel 2000; Iglesias-Páramo et al. 2006). Can these trends be attributed solely to the selection effects, or do they reflect some intrinsic differences between the two populations?

In order to answer this question, we have to compare the statistics of  $L_{tot}$  and of  $L_{60}/L_{UV}$  that are free from the selection effect. The selection effect is introduced by the so-called ‘Malmquist bias’ on both flux limited samples: For a given  $L_{tot}$ , galaxies with higher FIR-to-UV ratios have brighter  $L_{60}$ , therefore can be seen at larger distances (i.e. having a larger maximum finding volume  $V_{max}$ ) in a  $f_{60}$  limited sample. Similarly, for a given  $L_{tot}$ , galaxies with lower FIR-to-UV ratios have higher  $L_{UV}$  and therefore larger  $V_{max}$  in a UV flux limited sample. In what follows we shall compare the  $L_{tot}$  luminosity functions (LFs hereafter) of the two samples to exam whether they have the same intrinsic  $L_{tot}$  distributions. Because LFs are luminosity distributions of galaxies in a unit volume, they are not subject to the

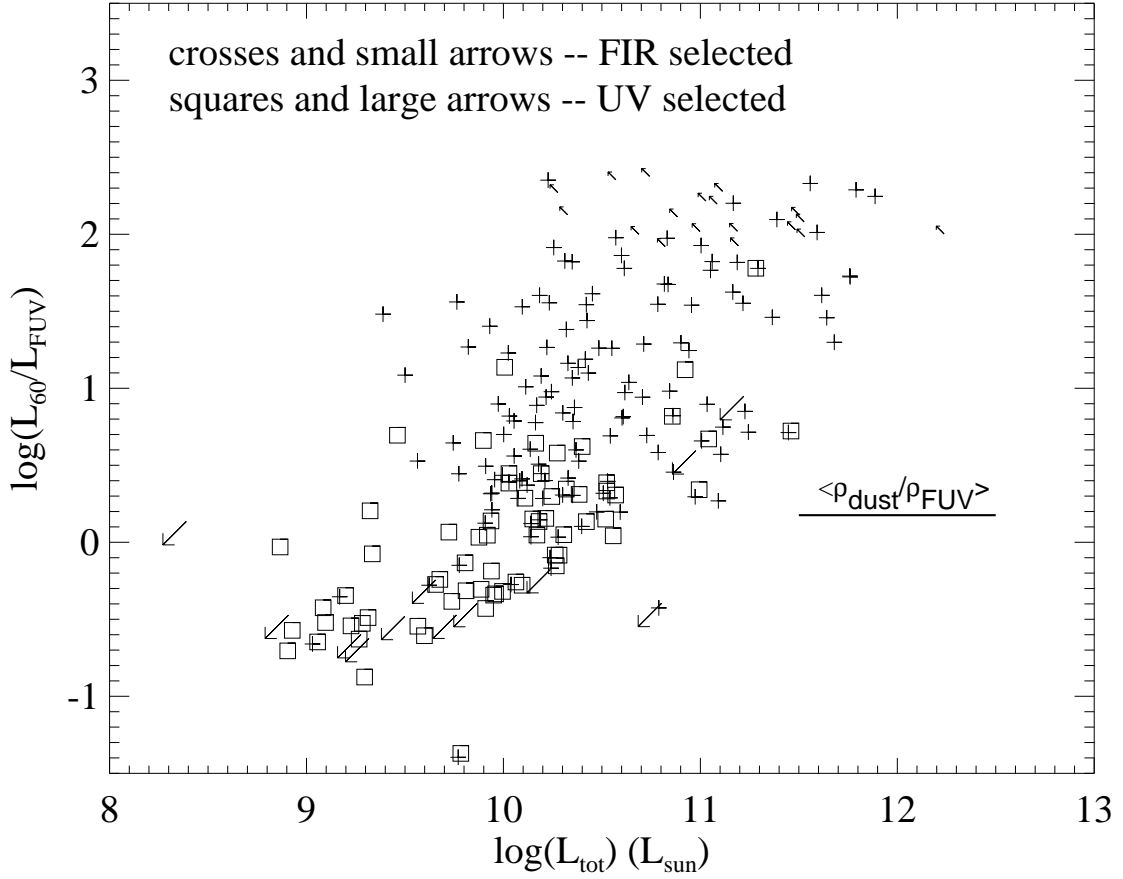


Fig. 2.— The  $L_{60}/L_{FUV}$  ratio vs.  $L_{tot}$  ( $L_{60}+L_{FUV}$ ) plot for UV (blue symbols) and FIR (red symbols) selected galaxies. The cosmic mean of the FIR/UV ratio,  $\langle \rho_{dust}/\rho_{FUV} \rangle$  is taken from Takeuchi et al. (2005), assuming  $L_{60} = 0.4 \times L_{dust}$ .

bias discussed above.

Here we exclude the sources whose IRAS fluxes are affected by the cirrus. Also UV galaxies not covered by the IRAS survey are dropped. This reduces the FIR sample to 151 galaxies and the UV sample to 81 galaxies. The IRAS detections of 5 UV galaxies are confused with other UV sources, therefore the corresponding IRAS fluxes are treated as upperlimits. Altogether 14 UV galaxies have only upperlimits for the IRAS flux. For galaxies in the FIR selected sample, 14 have only upperlimits for the FUV flux.

Define  $\phi_{\text{tot}}^{\text{FUV}}(L_k)$  as the  $L_{\text{tot}}$  LF of UV selected galaxies at  $\log(L_{\text{tot}}) = L_k$ ,  $\phi_{\text{FUV}}(L_i)$  the FUV (1530Å) LF at  $\log(L_{\text{FUV}}) = L_i$ , and  $P_{k,i}$  the conditional probability of finding UV galaxies of  $\log(L_{\text{FUV}}) = L_i$  in the bin of  $L_k - 0.5\delta_k < \log(L_{\text{tot}}) \leq L_k + 0.5\delta_k$ . Then

$$\phi_{\text{tot}}^{\text{FUV}}(L_k) = \sum_i P_{k,i} \phi_{\text{FUV}}(L_i) \delta_i / \delta_k. \quad (1)$$

Similarly, the  $L_{\text{tot}}$  luminosity function of FIR selected sample can be derived using the formula:

$$\phi_{\text{tot}}^{60}(L_{k'}) = \sum_j P_{k',j} \phi_{60}(L_j) \delta_j / \delta_{k'} \quad (2)$$

where  $P_{k',j}$  the conditional probability of finding FIR galaxies of  $\log L_{60} = L_j$  in the bin of  $L_{k'} - 0.5\delta_{k'} < \log(L_{\text{tot}}) \leq L_{k'} + 0.5\delta_{k'}$ . Data in our two samples are used in the calculations of the conditional probability functions  $P_{k,i}$  and  $P_{k',j}$ . In order to take into account the information content in the upper limits, the Kaplan-Meier (KM) estimator (Kaplan & Meier 1958; Feigelson & Nelson 1985; Schmitt 1985) has been applied in these calculations. We have chosen  $\delta_i=1$  mag for the  $L_{\text{FUV}}$  bin width,  $\delta_j=0.5$  dex for the  $L_{60}$  bin width, and  $\delta_k=0.5$  dex for the  $L_{\text{tot}}$  bin width. Other choices of the bin widths result in LFs with either larger scatters (bin widths too narrow) or coarse resolutions (bin widths too broad). The FUV LF and  $L_{60}$  LF are taken from Wyder et al. (2005) and Takeuchi et al. (2003), respectively.

The results are listed in Table 1 and plotted in Fig.3. In the  $L_{\text{tot}}$  range where they overlap, the LFs of the two populations are consistent with each other. The solid line is the best fit of the  $L_{\text{tot}}$  LF of M05, derived from a combined sample of UV and FIR selected galaxies. It is a log-normal function with the center at  $\log(L_{\text{tot}}/L_{\odot}) = 7.43$  and  $\sigma = 0.87$ . In bins of  $\log(L_{\text{tot}}/L_{\odot}) \gtrsim 10$ , our LFs are marginally higher than that of M05. In order to check whether this indicates over-estimation in our results, we also compared with the  $L_{60}$  LF of Takeuchi et al. (2003). There is a good agreement between our results and that of Takeuchi et al. (2003) for bins of  $\log(L_{\text{tot}}/L_{\odot}) \gtrsim 11$  (where  $L_{60}$  always dominates  $L_{\text{tot}}$ ), both are slightly higher than that of M05. At  $\log(L_{\text{tot}}/L_{\odot}) = 9$ , our results for both samples are lower than that of M05, possibly due to uncertainties caused by the small size of our samples compared to that of M05.



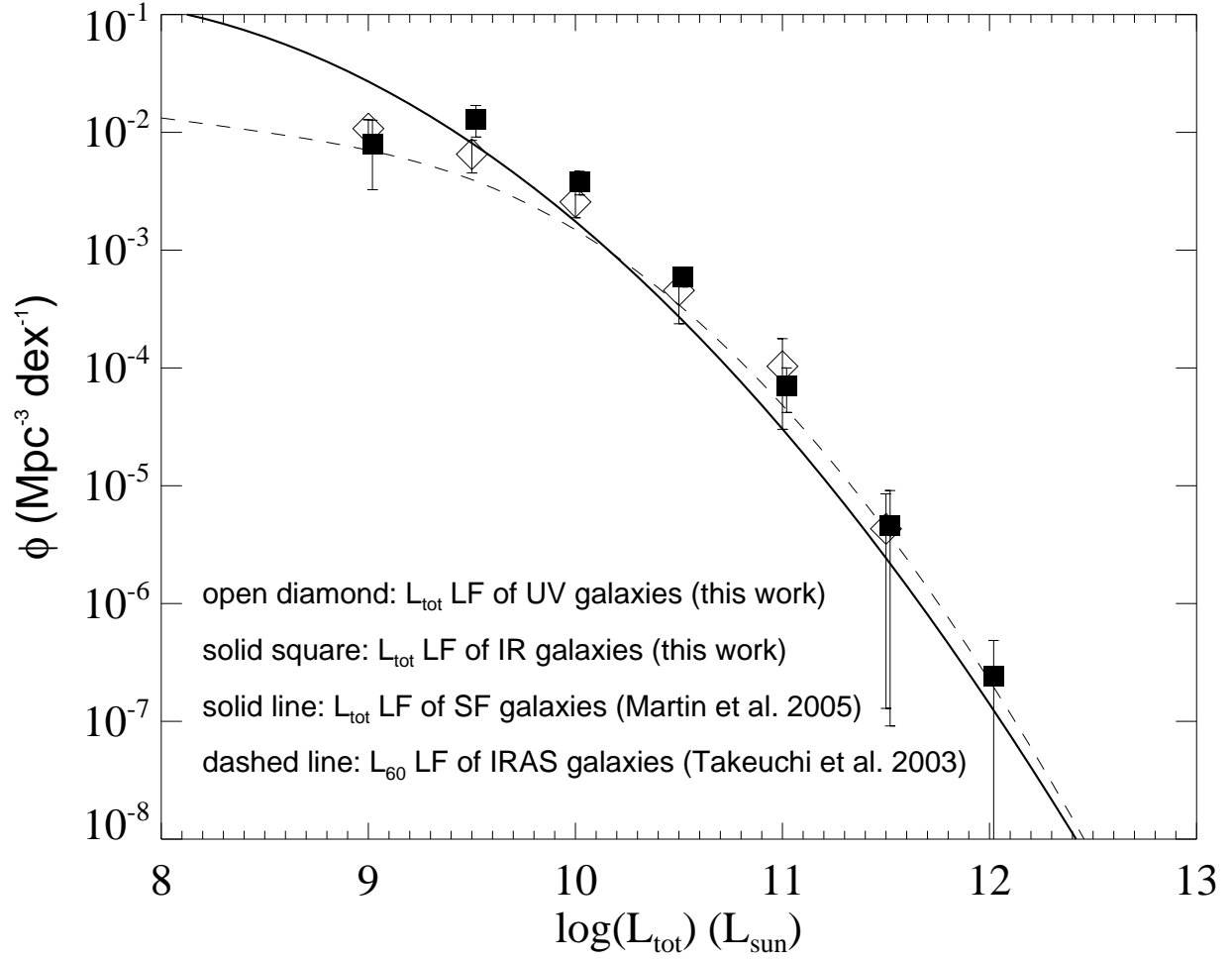


Fig. 3.— The  $L_{\text{tot}}$  ( $L_{60} + L_{\text{FUV}}$ ) luminosity functions of UV galaxies (open diamonds) and FIR galaxies (solid squares).

The above result is consistent with that the UV and the FIR samples are drawn from the same population of star-forming galaxies. However, the  $L_{tot}$  LF comparison could be insensitive to some differences. For example, in bins where  $L_{tot}$  is dominated by  $L_{60}$ , the differences between  $L_{FUV}$  distributions of two samples can be hidden by the similarity between  $L_{60}$  distributions, and vice versa. Therefore, in what follows we shall calculate the  $L_{60}$  LF of UV galaxies and compare it with the  $L_{60}$  LF of IRAS galaxies (Takeuchi et al. 2003), and calculate the  $L_{FUV}$  (1530Å) LF of FIR galaxies and compare it with that of GALEX galaxies (Wyder et al. 2005).

The formalism for the calculations of  $L_{60}$  LF of UV galaxies,  $\phi_{60}^{FUV}(L_{60})$ , and of  $L_{FUV}$  LF of FIR galaxies,  $\phi_{FUV}^{60}(L_{FUV})$ , is the same as that used in the calculations of  $L_{tot}$  LFs. One only needs to replace  $L_{tot}$  by  $L_{60}$  in Eq(1), and by  $L_{FUV}$  in Eq(2).

The results are listed in Table 2 and Table 3. In Fig.4,  $\phi_{60}^{FUV}(L_j)$  is compared with the  $60\mu m$  luminosity function of IRAS sources (Takeuchi et al. 2003). It appears that UV galaxies can account for the FIR luminosity function up-to  $L_{60} \sim 10^{11.5} L_{\odot}$ . Only ULIRGs of  $L_{60} \gtrsim 10^{12} L_{\odot}$  are missing in the UV sample. This is because ULIRGs are very rare in the local universe, and they are much fainter in UV. Therefore they are probed by UV surveys in a very much smaller volume compared to that probed by the FIR surveys. It should be pointed out that the UV LF of Wyder et al. (2005) excludes the contribution from broad-line AGNs identified using SDSS spectra. These are UV/optical selected QSOs and Seyfert 1 galaxies. According to Sanders et al. (1989) and Spinoglio & Malkan (1989), these sources never contribute more than 10% of the IR LF in the whole range of FIR luminosity. The comparison between FUV luminosity function of the FIR selected sample and the GALEX FUV luminosity function (Wyder et al. 2005) is in Fig.5. It shows that UV galaxies brighter than  $L_*(FUV)$  ( $\sim 10^{9.5} L_{\odot}$ ) are fully represented in the FIR selected sample. In fact there is a significant excess in the brightest bin ( $M_{FUV} = -21$ ) of the UV LF of FIR sources compared to the UV LF of Wyder et al. (2005), likely being caused by the exclusion of the broad-line AGNs in the latter. There is a marginal evidence for fainter UV galaxies of  $L_{FUV} < 10^{9.5} L_{\odot}$  being under-represented in the FIR selected sample, suggesting that a population of ‘FIR-quiet’ UV galaxies might be missing in the FIR selected sample.

### 3.2. FIR-to-UV v.s. $L_{tot}$ relations of UV and FIR galaxies

Let  $R = \log(L_{60}/L_{FUV}) = \log(L_{60}) - \log(L_{FUV})$ . For UV galaxies with a given  $L_{tot} = L_k$ , a ‘Malmquist-bias-free’ (i.e. selection effect free) indicator of mean FIR-to-UV ratio can be

Table 1. The  $L_{tot}$  ( $L_{60} + L_{FUV}$ ) Luminosity Functions of UV and FIR Selected Galaxies.

(1) $\log(L_{tot})$ ( $L_{\odot}$ )	(2) $\phi_{tot}^{FUV}$ ( $\text{Mpc}^{-3}\text{dex}^{-1}$ )	(3) error ( $\text{Mpc}^{-3}\text{dex}^{-1}$ )	(4) $\phi_{tot}^{60}$ ( $\text{Mpc}^{-3}\text{dex}^{-1}$ )	(5) error ( $\text{Mpc}^{-3}\text{dex}^{-1}$ )
9.0	1.076E-2	2.039E-3	7.948E-3	4.739E-3
9.5	6.522E-3	2.024E-3	1.298E-2	3.907E-3
10.0	2.564E-3	6.875E-4	3.804E-3	8.727E-4
10.5	4.548E-4	2.200E-4	5.978E-4	1.124E-4
11.0	1.033E-4	7.394E-5	7.077E-5	2.915E-5
11.5	4.310E-6	4.223E-6	4.574E-6	4.528e-6
12.0	...	...	2.430E-7	2.430e-7

Table 2. The FIR ( $60\mu m$ ) Luminosity Function of UV Selected Galaxies.

(1) $\log(L_{60})$ ( $L_{\odot}$ )	(2) $\phi_{60}^{FUV}$ ( $\text{Mpc}^{-3}\text{dex}^{-1}$ )	(3) error ( $\text{Mpc}^{-3}\text{dex}^{-1}$ )
8.0	2.117E-2	7.181E-3
8.5	8.679E-3	2.548E-3
9.0	3.219E-3	1.634E-3
9.5	2.875E-3	1.517E-3
10.0	1.555E-3	5.680E-4
10.5	2.090E-4	1.243E-4
11.0	9.078E-5	6.729E-5
11.5	3.057E-6	2.996E-6

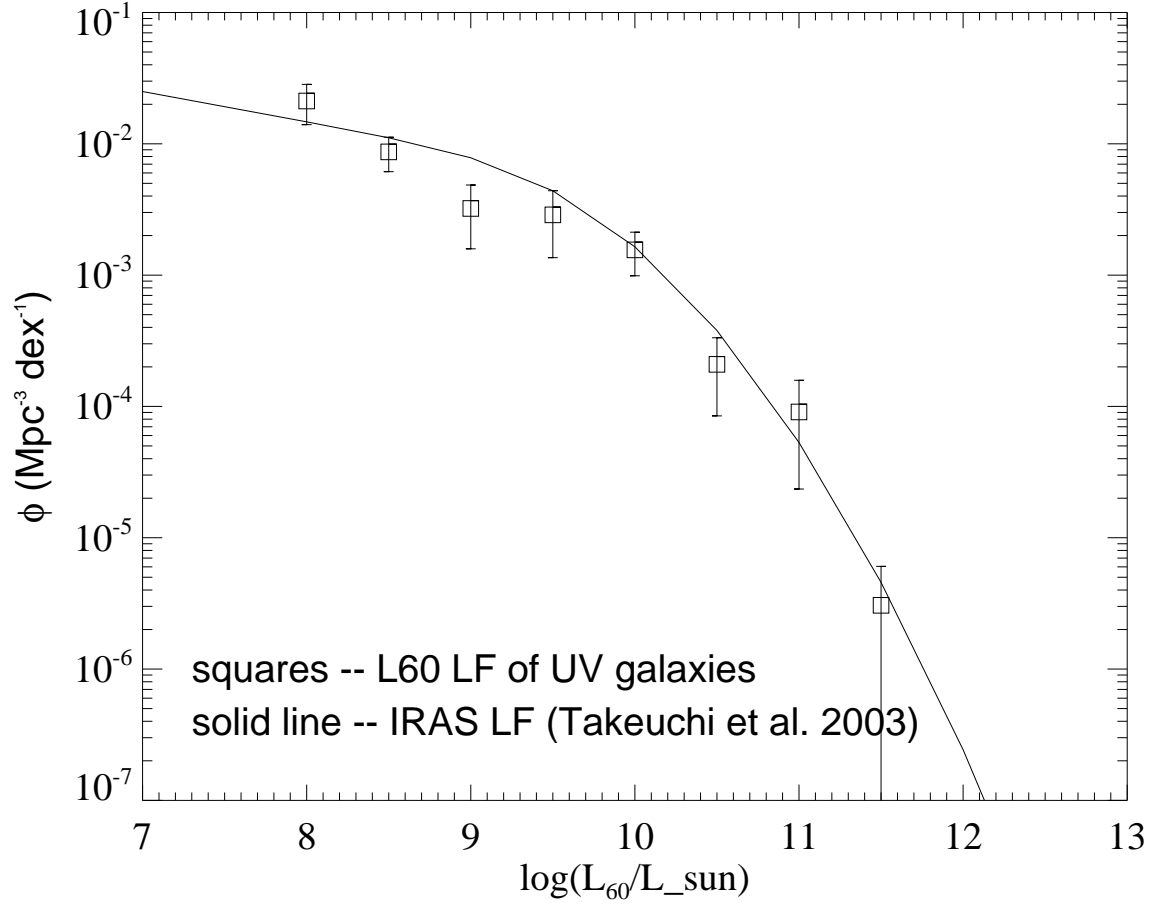


Fig. 4.— The  $L_{FIR}$  ( $60\mu\text{m}$ ) luminosity function of UV selected galaxies compared to the IRAS  $60\mu\text{m}$  luminosity function (Takeuchi et al. 2003).

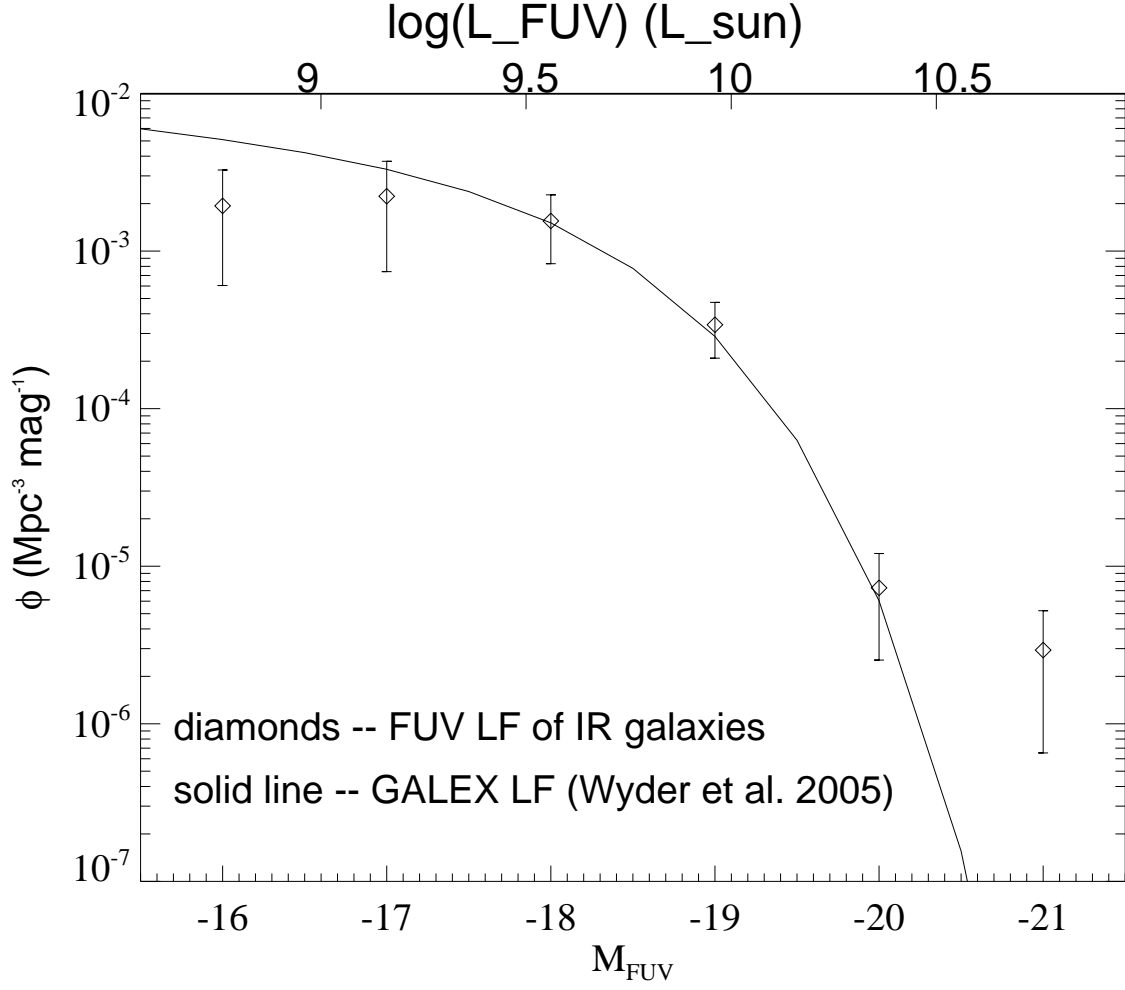


Fig. 5.— The FUV (1530Å) luminosity function of FIR selected galaxies compared to the GALEX FUV luminosity function (Wyder et al. 2005).

defined as follows:

$$R_{UV}(L_k) = \frac{\sum_{j,i} (L_j - L_i) P_{j,i} \phi_{FUV}(L_i) \delta_i}{\sum_{j,i} P_{j,i} \phi_{FUV}(L_i) \delta_i} \quad (3)$$

where  $P_{j,i}$  is the conditional probability of finding UV galaxies of  $\log(L_{FUV}) = L_i$  in the FIR luminosity bin  $L_j - 0.5\delta_j < \log(L_{60}) \leq L_j + 0.5\delta_j$ , and the summation goes through both indexes  $i$  and  $j$  including all bins satisfying the condition  $L_k - 0.5\delta_k < \log(10^{L_i} + 10^{L_j}) \leq L_k + 0.5\delta_k$ . A similar FIR-to-UV ratio indicator can be defined for FIR galaxies:

$$R_{FIR}(L_k) = \frac{\sum_{i,j} (L_j - L_i) P_{i,j} \phi_{60}(L_j) \delta_j}{\sum_{i,j} P_{i,j} \phi_{60}(L_j) \delta_j} \quad (4)$$

where  $P_{i,j}$  is the conditional probability of finding FIR galaxies of  $\log(L_{60}) = L_j$  in the FUV luminosity bin  $L_i - 0.5\delta_i < \log(L_{FUV}) \leq L_i + 0.5\delta_i$ . The variance of  $R_{UV}(L_k)$  and that of  $R_{FIR}(L_k)$ , respectively, are:

$$\sigma_{UV}^2(L_k) = \frac{\sum_{j,i} [(L_j - L_i) - R_{UV}(L_k)]^2 P_{j,i} \phi_{FUV}(L_i) \delta_i}{\sum_{j,i} P_{j,i} \phi_{FUV}(L_i) \delta_i}, \quad (5)$$

and

$$\sigma_{FIR}^2(L_k) = \frac{\sum_{j,i} [(L_j - L_i) - R_{FIR}(L_k)]^2 P_{i,j} \phi_{60}(L_j) \delta_j}{\sum_{j,i} P_{i,j} \phi_{60}(L_j) \delta_j}. \quad (6)$$

Results for  $R_{UV}$ ,  $R_{FIR}$ ,  $\sigma_{UV}$ , and  $\sigma_{FIR}$ , are listed in Table 4. As shown in Fig.6, there is no significant difference between the  $R_{UV}$  v.s.  $L_{tot}$  relation of UV galaxies and the  $R_{FIR}$  v.s.  $L_{tot}$  relation of FIR galaxies, again in consistence with the hypothesis that the two samples represent the same population, and their difference in Fig2. is due to the selection effect. Both  $R$  v.s.  $L_{tot}$  relations can be approximated by a simple linear relation:  $R = \log(L_{tot}) - 9.66$ , as shown by solid line in Fig.6. In the  $L_{tot}$  range covered by our samples, this relation is slightly lower than the non-linear relation between  $R$  and  $\log(L_{tot})$  (dashed curve in Fig.6) derived by M05 from the bi-variate function of their combined sample. It should be pointed out that the simple linear relation should not be extrapolated to galaxies of  $L_{tot} \lesssim 10^9 L_\odot$ , where a flatter relation is more likely (M05).

### 3.3. K band luminosity functions and stellar mass distributions

The NIR K band luminosity, very insensitive to both the dust extinction and the star formation history variation (Bell & De Jong 1991; Bell et al. 2003), is the best stellar mass indicator. The stellar mass distribution is one of the most important characteristics defining galaxy populations, therefore we would compare the K band LF of UV galaxies

Table 3. The FUV (1530Å) Luminosity Function of FIR Selected Galaxies.

(1)	(2)	(3)
$M_{FUV}$	$\phi_{FUV}^{60}$	error
(mag)	(Mpc <sup>-3</sup> mag <sup>-1</sup> )	(Mpc <sup>-3</sup> mag <sup>-1</sup> )
-16	1.936E-3	1.332E-3
-17	2.226E-3	1.486E-3
-18	1.552E-3	7.211E-4
-19	3.407E-4	1.316E-4
-20	7.286E-6	4.748E-6
-21	2.934E-6	2.281E-6

Table 4. The FIR-to-UV ratio ( $R = \log(L_{60}/L_{FUV})$ ) v.s.  $L_{tot}$  ( $L_{60} + L_{FUV}$ ) relations for UV and FIR Selected Galaxies.

(1)	(2)	(3)	(4)	(5)
$\log(L_{tot}/L_{\odot})$	$R_{UV}$	$\sigma_{UV}$	$R_{FIR}$	$\sigma_{FIR}$
9.0	-0.495	0.374	-0.451	0.282
9.5	0.133	0.600	-0.320	0.722
10.0	0.324	0.600	0.317	0.598
10.5	0.351	0.427	0.697	0.833
11.0	1.305	0.299	1.370	0.907
11.5	1.948	0.201	1.932	0.516
12.0	...	...	2.279	0.281

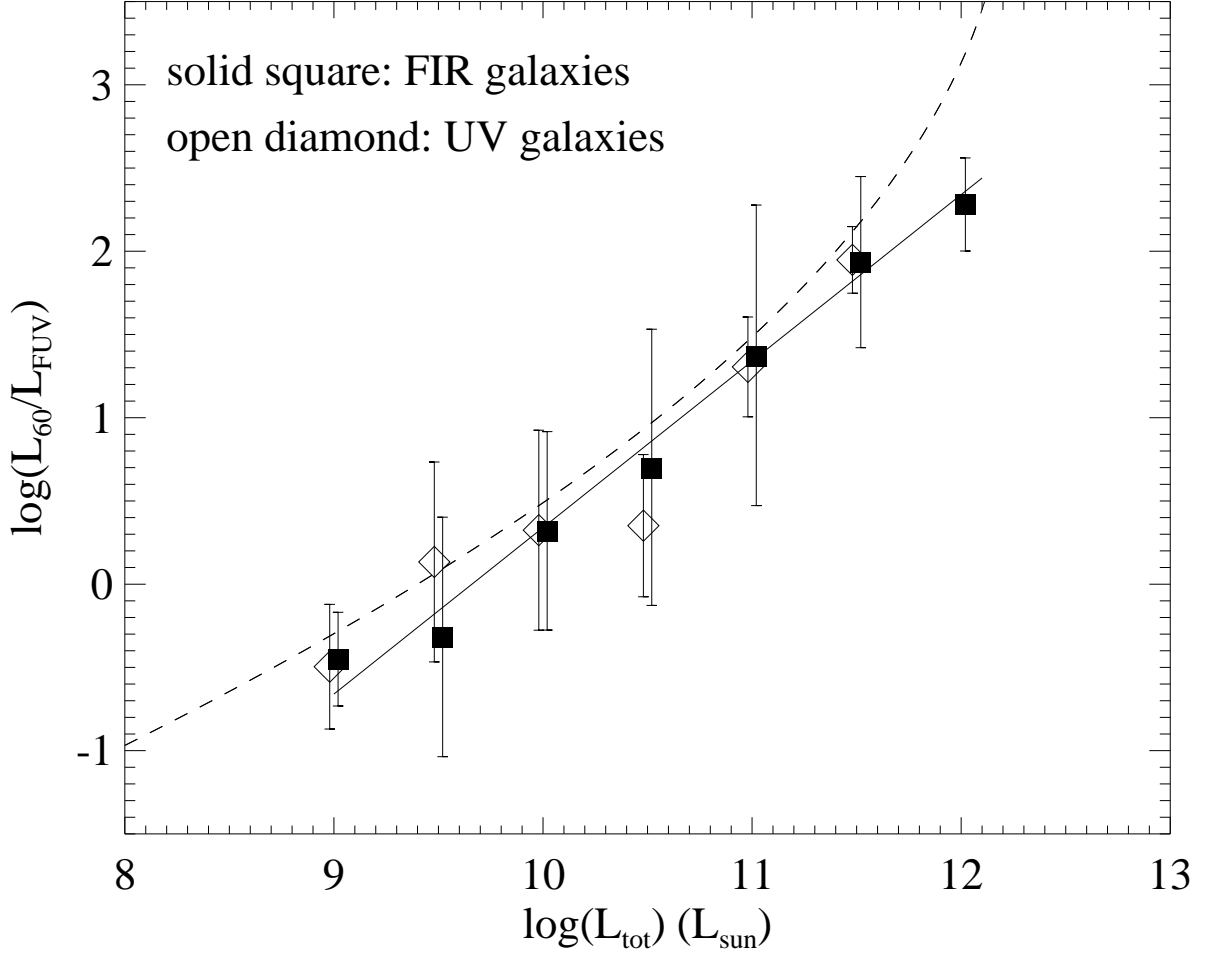


Fig. 6.— The FIR-to-UV ratio ( $R = \log(L_{60}/L_{FUV})$ ) v.s.  $L_{\text{tot}}$  ( $L_{60} + L_{FUV}$ ) relations for UV and FIR Selected Galaxies. Solid line:  $R = \log(L_{\text{tot}}) - 9.66$ . Dashed curve:  $R$  v.s.  $\log(L_{\text{tot}})$  relation derived by Martin et al (2005) for a combined sample.



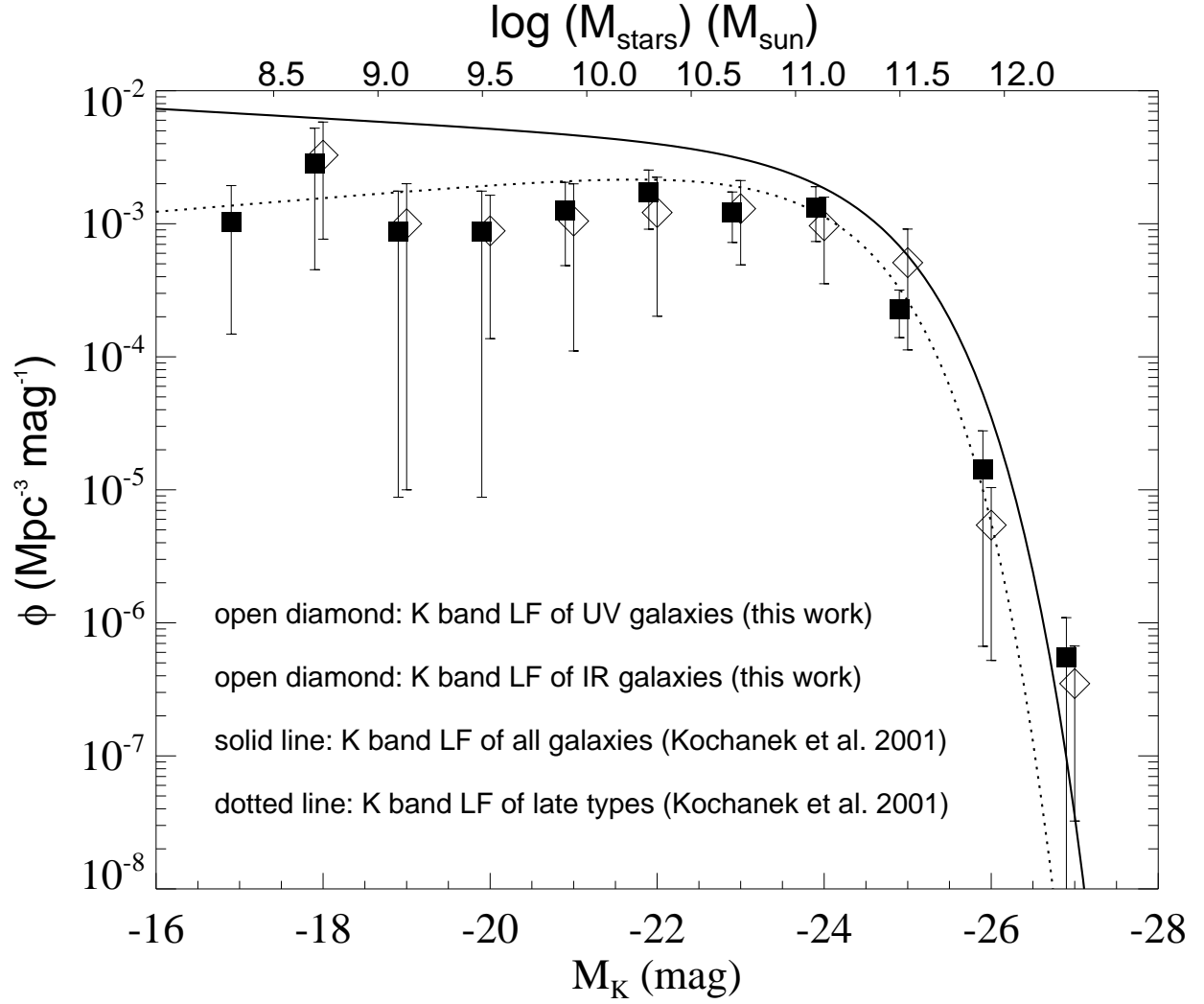


Fig. 7.— K band luminosity functions (stellar mass distributions) of UV and FIR selected samples.

with that of FIR galaxies. Because of the present of upper limits in the K band fluxes in both UV and FIR samples, we exploit the same formalism as presented in Eq(1) and Eq(2), and use KM estimator in calculating the conditional probability functions  $P(M - 0.5\delta < M_K \leq M + 0.5\delta | L_{FUV})$  and  $P(M - 0.5\delta < M_K \leq M + 0.5\delta | L_{60})$ . In Fig.7, the resulted K LFs of the two samples are compared with each other. No significant difference is found between them. It is interesting to note that both K LFs are consistent with the K LF of late-type galaxies derived by Kochanek et al (2001), specified by a Schechter function with  $\phi_0 = 0.0101$ ,  $\alpha = -0.87$  and  $M_* = -22.98 + 5. * \log_{10}(h_0) - \delta$ , where  $h_0 = 0.7$  and  $\delta = 0.2$  (the difference between the isophotal magnitude and the 'total' magnitude, Cole et al. 2001). The conversion factor  $M_{\text{stars}}/L_K = 1.32M_{\odot}/L_{\odot}$ , which is derived for a stellar population with constant star formation rate and a Salpeter IMF (Cole et al. 2001), is assumed when converting the K band luminosity to stellar mass.

#### 4. Discussion

Our results indicate that bulk of  $z=0$  galaxies selected in the UV and FIR samples are from the same population of active star forming galaxies. In particular, galaxies in the two samples have indistinguishable  $L_{\text{tot}}$  LFs. And their FIR-to-UV ratio v.s.  $L_{\text{tot}}$  relations, after correction for the Malmquist bias, are consistent with each other. Therefore, the well documented results that galaxies in the UV flux limited samples tend to have lower  $L_{\text{tot}}$  and lower FIR-to-UV ratios for a given  $L_{\text{tot}}$  than those galaxies in the FIR flux limited samples are purely due to the selection effect.

The only sign for a possible difference between UV and FIR populations is a marginal deficiency of galaxies of low UV luminosity in the FIR selected sample, indicating the existence of an 'FIR-quiet' UV population. Indeed, it has been known that there is a population of low-metallicity, low dust content 'blue compact dwarf' galaxies. The prototype is I ZW 18, the galaxy with one of the lowest metallicity of 1/50 solar (Searle & Sargent 1972). I ZW 18 has never been detected in FIR. The FUV magnitude of I Zw 18 derived from its GALEX image is 15.75 mag (Gil De Paz, private communication). Its IRAS upper limit of  $f_{60\mu m} < 0.2$  Jy corresponds to a upperlimit of  $L_{60}/L_{FUV} < 0.27$ . There are only a few percent of galaxies in our UV sample have such low  $L_{60}/L_{FUV}$  ratio, indicating a low contribution from these 'FIR-quiet' galaxies to the overall UV population. This is in agreement with the result in Fig.7 which shows no significant difference in the K LFs (i.e. stellar mass functions) of the UV and FIR galaxies. Furthermore, because they have rather low UV and FIR luminosities, these galaxies contribute negligibly to the total SFR of the local universe. It will be interesting to know whether in the earlier universe more star forming galaxies becoming 'FIR

quiet’, given the lower metallicity in high  $z$  galaxies and marginal evidence for net increase of the faint end of the UV LF (Arnouts et al. 2005). The new results of Burgarella et al. (2006) on LBG galaxies at  $z \sim 1$  suggest the existence of a population of low-attenuation, bright UV galaxies at that redshift.

There are no ULIRGs in our UV sample. It is generally true that ULIRGs are absent in UV samples of sizes less than a few 1000s. In the local universe, LIRGS/ULIRGs contribute less than a few percent to the total star formation in all galaxies (Soifer & Nuegebauer 1998). Therefore the absence of them in UV selected samples does not introduce significant bias in the estimate of total starformation rate. But in the earlier universe of  $z \gtrsim 1$ , this bias may be more significant. According to Le Floch et al. (2005), about more than 10% of star formation at  $z \sim 1$  is due to ULIRGs.

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